MM

M.V. ARCTIC SPECIAL REPORT

ON LAKE MELVILLE PROBE

(TP 3809E)

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The contents of this report reflect the views of the authors and not necessarily the official views or policies of the Transportation Development Centre.

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17. Abstract

This special report describes the experimental voyage to Lake Melville by the M.V. ARCTIC in February/March 1981 and identifies the various parameters measured during the testing program. The purpose of this probe through the Labrador pack ice and the ice environment of Lake Melville was to demonstrate the feasibility of a commercial wintertime marine service through the lake as part of a study addressing the industrial development of this Labrador region. The M.V. ARCTIC was seen to be the only Canadian commercial cargo carrying ship potentially capable of undertaking this transit, and added benefit was seen in this program to add significantly to the bank of ice performance data already assembled for the M.V. ARCTIC. The report addresses both aspects of the probe, and describes both the successful transit of the Labrador Pack and the Lake, and also the ship performance trials undertaken en route. The test program included controlled icebreaking runs through ridged and level ice at various power levels and with the bubbler system on and off. Turning manoeuvers were also undertaken, with and without initial heeling of the ship. The ice impact and vibration effect on the hull, propulsion and steering were recorded. Ice conditions were carefully characterized prior, during and subsequent to the voyage.

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17. Résumé

Ce rapport décrit le périple fait à titre expérimental jusqu'au lac Melville par le cargo brise-glace Arctic en février et mars 1981 et identifie les divers paramètres mesurés durant le programme d'essai. Le but de cette incursion dans le pack glacé du Labrador et jusque dans le lac Melville recouvert de glaces était d'établir la faisabilité d'un service maritime commercial en hiver et empruntant ce lac, dans le cadre d'une étude envisageant la mise en valeur industrielle de cette région du Labrador. L'Arctic a été choisi pour ce périple parce qu'il est considéré comme le seul cargo canadien capable d'une telle entreprise et parce que ce programme ajoutait avantageusement à la banque de données rassemblées sur le comportement de ce navire dans les glaces. Le rapport traite de ce double aspect du périple en rendant compte tant de la traversée réussie dans le pack glacé et de la navigation dans le lac que des essais faits en chemin sur le comportement du navire. Ces derniers ont comporté des opérations de déglaçage dans des conditions contrôlées, à travers des crêtes de glace et des glaces d'épaisseur uniforme, à divers régimes moteur et avec ou sans l'aide du système à bulles d'air. Des manoeuvres de giration ont également été faites, avec et sans gîte initiale. L'impact des glaces et l'effet des vibrations induites sur la coque et les systèmes de propulsion et de direction furent enregistrés. La nature et la concentration des glaces ont été déterminées soigneusement avant, durant et après le périple.

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1.0 INTRODUCTION

Lake Melville, Labrador, has been the scene of intense research for several years. The objective of these efforts was to show that an industrial complex, probably based on an aluminum smelter using electric power from new dams on the Lower Churchill River, could be supported by ships throughout the year.

The only commercial cargo carrying ship in Canada which was potentially capable of transitting Lake Melville in winter was M.V. ARCTIC. This ship is Arctic Class II in accordance with the Canadian Arctic Shipping Pollution Prevention Regulations (CASPPR).

The ARCTIC's raison d'etre is to conduct commercial activities in ice-covered waters. This mandate could be effectively fulfilled by operation in Lake Melville from December to May and in the Arctic from June to November. North Water Navigation, the ship's operator, therefore proposed to the Government of Newfoundland that the ARCTIC conduct a demonstration voyage into Lake Melville and during this voyage perform a series of scientific experiments. A map of eastern Canada showing the geographic location of Lake Melville is attached as Figure 1.

To ensure success of the probe, it was appropriate that several sponsors be found. These sponsors are listed below.

a) Arctic Pilot Project
   - Petro-Canada
   - Nova, An Alberta Corporation
   - Dome Petroleum Limited
   - Melville Shipping Ltd.
b) Canarctic Shipping Ltd.
c) CN Marine Inc.
d) Government of Newfoundland (Department of Industrial Development and the Department of Regional Economic Expansion)
e) North Water Navigation Ltd.
f) Transport Development Centre

In addition to these sponsors the National Research Council - Arctic Vessel and Marine Research Institute in Ottawa provided equipment and scientific advice and assistance at no cost to the project.

All phases of the test program were under the management of Melville Shipping Ltd. (MSL). This included the preparation of the test program and project manual, the logistics and execution of the field program and the data analysis and preparation of the final report. The test program

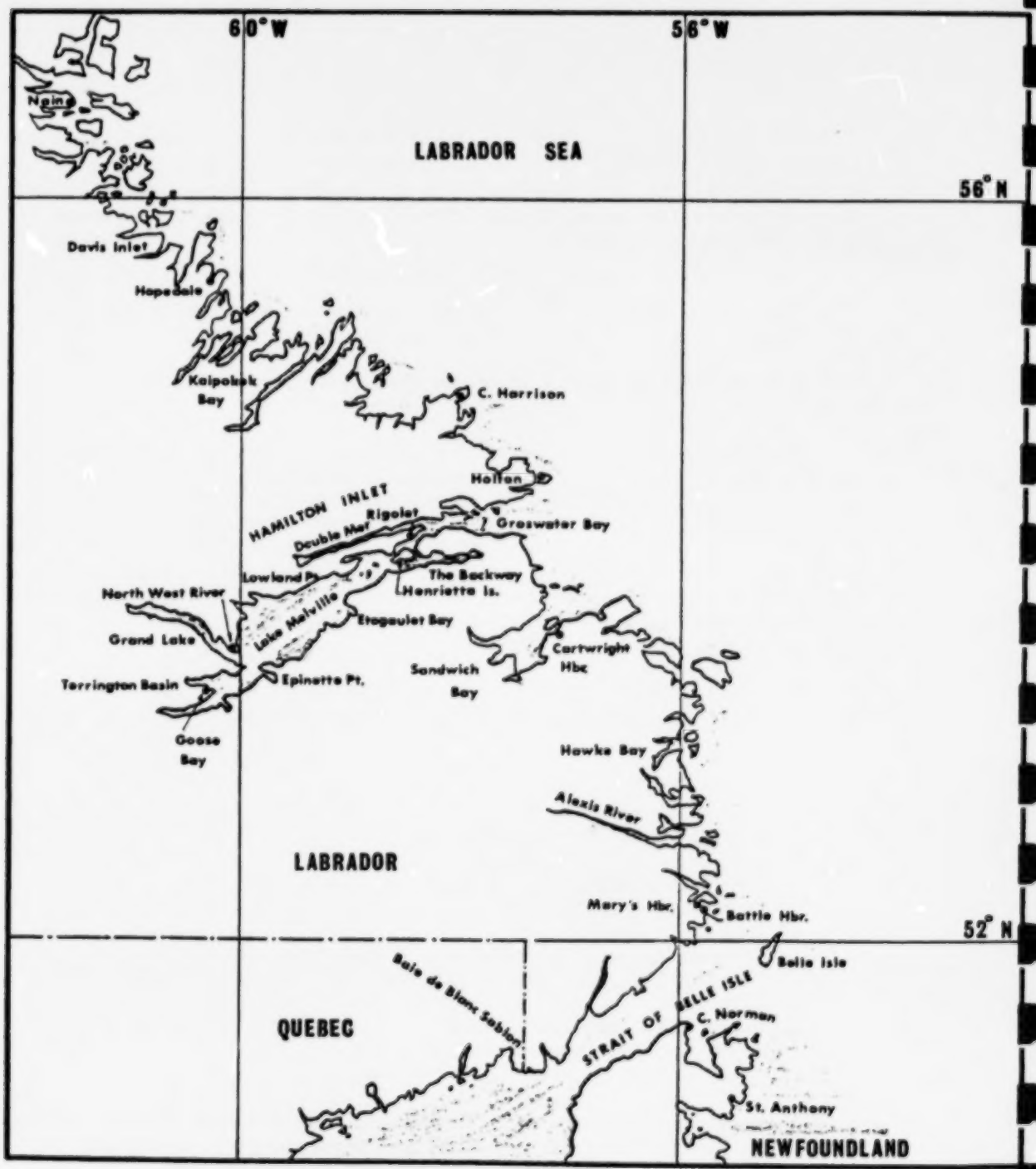


FIGURE 1

LAKE MELVILLE & APPROACHES TO HAMILTON INLET.

and project manual, the logistics and execution of the field program and the data analysis and preparation of the final report. The test program team was supplied by MSL, the National Research Council - Arctic Vessel and Marine Research Institute (NRC), Fenco Consultants Ltd., MacLaren Plansearch (MPS), German and Milne (G & M) and Lloyd's Register of Shipping (LRS) and in addition, local people were used as on-ice assistants.

Prior to the ARCTIC approaching Lake Melville, a series of pre-probe surveys was performed to:

a) Map the freeze-up patterns (Study performed under the Sponsorship of the Government of Newfoundland).
b) Measure ice thickness and ridge severity.
c) Assess a route of least resistance through the Lake ice to the area of North West River.
d) Prepare lines of know ice thickness and pre-select the areas for performing each ship performance test in the program.

The probe was started on February 27, 1981 and completed on March 3, 1981. During the probe, the ARCTIC completed a round trip to the area of North West River and performed a series of formal experiments.

The Lake Melville probe was followed by a series of surveys to determine the rate of refreezing of the ship's track, the prevailing meteorological conditions, the continuing growth and decay of the ice cover, the variation of ice strength with time and the break-up patterns.

Listed below is a chronological log of the various voyage activities from the time of arrival at the Labrador Sea ice edge until exit from Lake Melville after completion of the test program:

Wed 25 Feb

M.V. Arctic arrived at the ice edge in the Labrador Sea and proceeded 18 km through 10-tenth ice cover at an average speed of about 6.9 m/s (13.5 knots). C.C.G.S. FRANKLIN and the ARCTIC rendezvoused at the ice edge in Labrador Sea and the test personnel, advisors and representatives transferred to the ARCTIC by helicopter. M.V. ARCTIC proceeded through 10-tenth white and grey ice (thickness 25 cm) where recordings were made of rudder torque. After passing through open water in The Narrows, the ARCTIC stopped in ice (thickness 45 cm) in Lake Melville near Henrietta Island at 1700 hours.

Thu 26 Feb

M.V. ARCTIC and C.C.G.S. FRANKLIN remained stationary at their February 25th location throughout the day, pending the resolution of objections raised by some members of the local communities.

Fri 27 Feb

The ARCTIC moved from Henrietta Island at the start to Etagaulet Point at end of the day.

Ship speed/power tests at various power settings were performed in level ice with the bubbler system on and off, in ice thickness from 0.58 m to 0.90 m.

Sat 28 Feb

The ARCTIC moved from Etagaulet Point at the start to Lowland Point at end of the day.

Sun 01 Mar

The ARCTIC moved from Lowland Point at the start to Nebavik Point and returned to Julia Point at the end of the day.

The vessel performance tests completed were:

a) Speed/power tests in level ice at thicknesses from 0.8 m to 1.1 m and snow cover of 4 cm to 7 cm and various engine power/combinator positions, with the bubbler system on and off.
b) Turning tests at full power and various rudder angles, with the bubbler system on and off, in ice thickness of 0.8 m to 1.3 m.

Mon 02 Mar

The ARCTIC moved from Julia Point to Etagaulet Point.

Ship performance tests completed were:

a) Level ice ramming in ice thicknesses of 0.85 m to 1.31 m at various power settings.
b) Ridge ramming at full power.

Tue 03 Mar

The ARCTIC moved from Etagaulet Point to Neveisik Island.

Ship performance tests conducted were:

a) Turning tests at full power with 5° heel and with the bubbler system on.
b) Speed/power tests in broken channel at various power settings, with the bubbler system off.

Wed 04 Mar

M.V. ARCTIC departed from Lake Melville.

No measurements were made on the outbound voyage in either Groswater Bay or the Labrador Sea due to the lack of significant ice in these waters.

The following aspects of the program were successfully completed:

a) Transit to the vicinity of North West River.
b) Test Program inclusive of:
   - Speed/power in level ice at two drafts and trims, at various power levels, in various ice thicknesses and with the bubbler system on and off.
   - Level ice ramming at various power levels.
   - Ridge ramming through a profiled ridge.
   - Turning manoeuvres at various rudder angles.
   - Channel break-out.
   - Turning manoeuvres with and without the bubbler system operating and with and without heel.
   - Speed/power in a broken channel at various power levels with the bubbler system off.

A map of Lake Melville showing the ship's track and the test locations is attached as Figure 2.

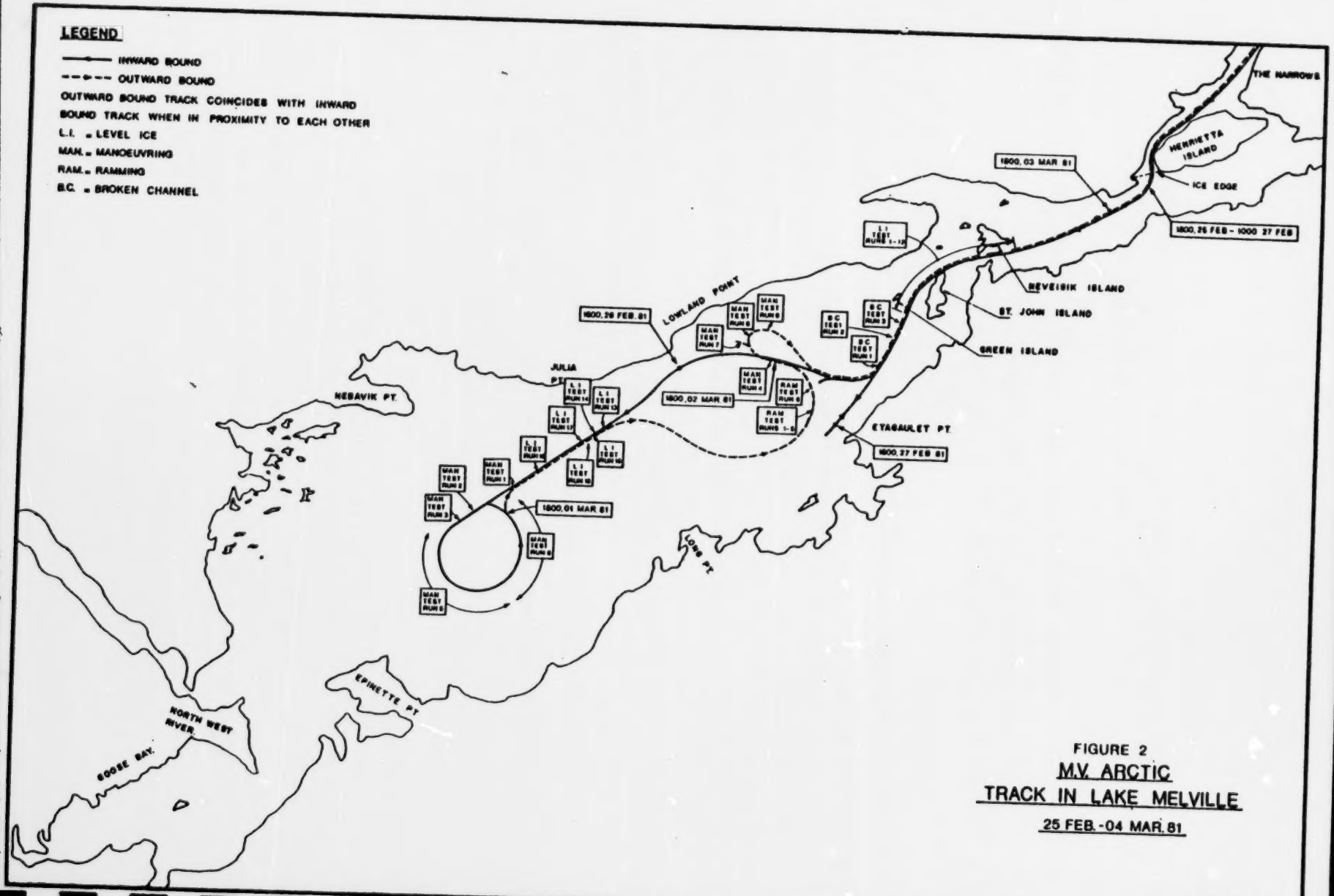


FIGURE 2

M.V. ARCTIC

TRACK IN LAKE MELVILLE

25 FEB.-04 MAR. 81

2.0 TEST PROGRAM, PROCEDURES, AND DATA

2.1 Level Ice Speed/Power Tests

2.1.1 Procedure

Level ice speed/power tests were conducted in two locations in the Lake. Figure 2 indicates the locations. These two locations were chosen to provide relatively level, smooth ice and to provide a variation in thickness in excess of 150 cm. The process of conducting the tests is outlined below.

a) An on-ice test party was deposited on the ice, adjacent to the ship prior to starting the test runs. The duties of this party were to characterize the ice cover along the tested track. The data collected by the ice party was:

- Ice thickness
- Ice salinity
- Ice temperature
- Ice strength
  - . Confined compressive (borehole jack)
  - . Unconfined compressive (later in laboratory using uniaxial compression press)
  - . Flexural (NRC beam test rig)
  - . Crystallography analysis (later in the laboratory)

The thickness, temperature and confined compressive strength data was collected immediately after ship passage. The flexural strength data was collected in the ship track vicinity before or after the tests. Salinity, unconfined compressive strength and crystallography data was obtained from cores taken at the test site and transferred in an insulated box to the ship's cold rooms for later analysis.

Generally, three measurements of thickness and confined compressive strength of the ice were taken during each test run. In addition flexural strength was measured in three test locations.

b) The intention was to perform test runs, in both locations, at three power levels and to repeat the runs to identify any random peculiarities which may arise. The ship test party consisted of:

- Test director on ship's bridge
- Test engineer on ship's bridge

- Test engineer in engine room
- Permanent instrumentation engineer in laboratory
- Temporary instrumentation engineer in laboratory

Before any measurements were recorded by the permanent or temporary instrumentation systems, the ship's speed and propeller shaft power were allowed to stabilize. The ship's speed was measured by three methods viz:

a) by direct observation of fixed markers on the ice
b) from a calibrated T.V. screen
c) by the ship's 'Doppler Log'

It was found that the speed derived from the T.V. was generally 0.25 knots slower than a). The propeller shaft power was derived from the temporary instrumentation fitted to the propeller shaft.

2.1.2 Data

A total of eighteen runs of level ice speed/power tests in the Lake Melville were recorded. Table 1 provides in detail the data collected for each run which is identified with the test time, location and the applicable data tapes recorded automatically during the test periods by:

- Permanent data acquisition system of the M.V. ARCTIC
- Temporary data acquisition system for vibration measurement with an Ampex FM analogue signal tape recorder Type FR1300A and
- Video recorder using a monitoring television camera positioned on the port side of the ship's shoulder.

Also presented in Table 1 are the items of ship data and meteorological data recorded manually by test engineers onboard during the test, and the ice properties measured by ice survey engineers in locations adjacent to the test site. Seventeen data tapes recorded from the permanent data acquisition system and 5 data tapes recorded from the analogue signal tape recorder were obtained from the Lake Melville probe. Detailed catalogues of these data tapes are exhibited in Section 2.5 and 2.6. Seven video tapes have been recorded from the shoulder-mounted camera and a list of the recording times is given in Table 2.

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Data*
Date (Month/Day)	2/27	2/27	2/27	2/27	2/27	2/27	2/27	2/27	2/27	2/27	2/27	2/27	3/1	3/1	3/1	3/1	3/1	3/1	
Start Time	11:08	11:16	11:20	11:30	11:46	11:49	12:00	12:45	12:50	12:58	13:09	13:17	09:24	09:39	10:00	10:07	10:17	12:11	
Stop Time	11:16	11:20	11:30	11:46	11:49	12:00	12:10	12:50	12:58	13:09	13:17	13:35	09:39	10:00	10:07	10:17	10:30	12:20	
Location = Lat. (N)	54° 58'	54° 58'	54° 58'	54° 58'	54° 58'	54° 57'	54° 57'	54° 56'	54° 55'	54° 55'	54° 54'	54° 54'	53° 47'	53° 47'	53° 46'	53° 46'	53° 46'	53° 44'	
Long. (W)	58° 48'	58° 50'	58° 51'	58° 52'	58° 54'	58° 55'	58° 56'	58° 58'	58° 58'	58° 58'	58° 59'	58° 59'	59° 29'	59° 31'	59° 32'	59° 33'	59° 33'	59° 39'	
Permanent Data Tape No.	C8	C8	C8	C8	C8	C8	C8	C9	C9	C9	C9	C9	C11	C11	C11	C11	C11	C12	
Acquisition System: File No. (original tapes)	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	T
Vibration Measurement: Reel No.	2	2	2	2	2	2	2	2	2	2	2	2	4	4	4	4	4	4	T
Video Recording: Cassette No.	V1	V1	V1	V1	V1	V1	V1	V1	V1	V1	V1	V1	V3	V3	V3	V3	V3	V3	T
Ship Data																			
Speed, Doppler	x	x	x	x	x	x	x	x	x	x	x	x							
Speed, Marker	x	x	x	x	x	x	x	x	x	x	x	x							
Speed, Video Monitor													x	x	x	x	x		R1
Heading	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	R1
Rudder	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		W
Combinator	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
Stability Data	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
R.P.M.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	P1
Engine Data	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
Electrical Load Data	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	R1
Propeller Shaft Thrust	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
Propeller Torque	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
Bubbler System	off	off	off	off	on	on	on	on	on	on	off	off	on	on	off	off	off	on	R1
Draught	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	R1
Draught	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
Ice/Meteorological Data																			
Ice Cover	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	R2
Ice Thickness	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	R2
Snow Cover													x	x	x	x	x	x	R2
Flexural Strength	x			x	x								x	x	x	x	x		R2
Confined Compressive Strength	x	x	x	x	x	x							x	x					R2
Unconfined Compressive Strength													x	x	x	x	x		R2
Ice Temperature Profile	x	x	x	x	x	x					x	x	x	x	x	x			R2
Ice Salinity Profile													x				x		R2
Crystallography													x				x		R2
Air Temperature				x					x								x		R3
Air Pressure																	x		W
Water Depth	x	x	x	x	x	x	x	x	x	x	x	x		x			x		W
Wind Speed, Direction				x					x										W
Visibility				x					x					x			x		W

* Data Location:

R1: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.1, M.S.L. (1982)
R2: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.2, M.S.L. (1982)
R3: "M.V. ARCTIC Probe into Lake Melville, Labrador, Ice Property Measurements", Arctic Vessel and Marine Research Institute (1981)
T: Magnetic Tapes
W: Lake Melville Probe Work Sheets

DATA COLLECTION FOR THE LEVEL ICE SPEED/POWER TESTS

Table 1

INDEX OF DATA COLLECTED

Tape No.	Date	Time
V-1	81-02-27	10:56 - 18:04
V-2	81-02-28	09:44 - 17:30
V-3	81-03-01	08:14 - 17:39
V-4	81-03-02	08:04 - 17:36
V-6	81-03-03	14:30 - 15:35
V-7	81-03-03	15:35 - 16:00

CATALOGUE OF VIDEO TAPES RECORDED FROM

SHOULDER-MOUNTED T.V. CAMERA

Table 2

2.2 Ramming Tests

2.2.1 Procedure

The ARCTIC's ramming capabilities were examined in two ways; first by ramming level ice at various speeds and secondly by ramming ice ridges.

The level ice ramming tests were conducted at a variety of power levels. It was hoped that by varying the approach speed and power levels that a relationship could be obtained for penetration distance as a function of ice characteristics and ship's speed and power. Five rams were conducted in level ice.

The ARCTIC's ridge ramming capabilities were examined in two ways; first by monitoring the number of rams required during normal ice transit operations in the Lake and secondly during a pre-arranged ridge ramming test on the Etagaulet Ridge.

The ARCTIC was required to ram on a few occasions while moving about the Lake. On most occasions only one ram was required. It can be surmised that during these events, the ship penetrated well into the ridge during the approach. The single ram required to fully penetrate the ridge was usually conducted at a contact speed of 3.0 - 4.0 knots and only in one case was more than one ram required. In that case, the ARCTIC met two ridges close together and rammed at a 30 - 45° angle. The total width of the two ridges is estimated at 150 m and five rams were required including the initial contact.

An organised ridge ramming experiment was carried out on the Etagaulet Ridge in the location shown on Figure 2. The ridge was profiled in several areas. The profiles were obtained by drilling holes at intervals of 10 metres. Several borehole jack tests were performed to assess the compressive strength profile through the ridge thickness. Markers were placed at each 10-metre interval to allow measurement of "distance travelled" and "elapsed time".

The ship was manoeuvred into position close to the profile area, approximately 100 m before the ridge. After backing-down the broken channel a distance of about 1/3 of a ship length, full ahead power was applied. The speed at contact with the intact ice sheet was approximately 4.30 knots.

2.2.2 Data

In Table 3 is shown a tabulation of the data collected for the organised ramming experiments in level or ridged ice in the lake. The table is presented in the same format as in Section 2.1.2. Five tests were conducted in level ice and one test was carried out on a ridge, all in a location near Etagaulet Point.

2.3 Manoeuvring

2.3.1 Procedures

Several manoeuvring tests were conducted to determine:

- Sensitivity of "Radius of Turn" to rudder angle.
- Ability to break out from a previously broken channel
- Turning circle dimension in various ice thicknesses for a variety of ship conditions.

a) Sensitivity to Rudder Angle

To test the ship's turning ability as a function of rudder angle a test was conducted. The ship was established on a steady course and at steady power with the rudder amid-ships. The rudder was then moved to 5° to port and the time to change the heading by 5° was noted. This procedure was then repeated for 10° and 15° port rudder, the time to change the heading by 5° being noted each time.

Due to lack of space the full range of rudder angles could not be examined.

b) Channel Breakout

To identify the level of concern which should reasonably be associated with the ship's ability to break out from a previously broken channel, a series of tests was performed. Due to the uncertain nature of this type of test - it is mainly dependent on the ship's ability to make an entrance into the channel side - only one meaningful test was recorded.

c) Turning Circles

Turning circle tests were conducted. These tests were performed in two locations in the Lake, indicated on Figure 2.

Run No.	1	2	3	4	5	6	Data Location*
Date (Month/Day)	3/2	3/2	3/2	3/2	3/2	3/2	
Start Time	14:16	14:23	14:32	14:45	14:50	15:46	
Stop Time	14:18	14:25	14:35	14:49	14:54	15:50	
Location = Lat. (N)	53° 48'	53° 48'	53° 48'	53° 49'	53° 49'	53° 49'	
Long. (W)	59° 08'	59° 08'	59° 08'	59° 07'	59° 07'	59° 07'	
Permanent Data Tape No.	C14	C14	C14	C14	C14	C14	T
Acquisition System: File No. (original tapes)	01	02	03	04	05	06	
Vibration Measurement: Reel No.	5	5	5	5	5	5	T
Video Recording: Cassette No.	V4	V4	V4	V4	V4	V4	T
Ship Data							
Speed, Doppler							
Speed, Marker	x	x	x	x	x	x	R1
Speed, Video Monitor							
Heading	x	x	x	x	x	x	W
Rudder	x	x	x	x	x	x	W
Combinator	x	x	x	x	x	x	W
Stability Data	x	x	x	x	x	x	W
R.P.M.	x	x	x	x	x	x	W
Engine Data							
Electrical Load Data							
Propeller Shaft Thrust	x	x	x	x	x	x	W
Propeller Torque	x	x	x	x	x	x	W
Bubbler System	off	off	off	off	off	on	W
Draught (F)	x	x	x	x	x	x	W
Draught (A)	x	x	x	x	x	x	W
Ice/Meteorological Data							
Ice Cover	x	x	x	x	x	x	R2
Ice Thickness	x	x	x	x	x	x	R2
Snow Cover							
Flexural Strength							
Confined Compressive Strength	x	x	x	x	x	x	R2
Unconfined Compressive Strength	x	x	x	x	x	x	R2
Ice Temperature Profile	x	x	x	x	x	x	R2
Ice Salinity Profile	x	x	x	x	x	x	R2
Crystallography	x	x	x	x	x	x	R3
Ridge Thickness						x	R2
Ridge Consolidation Depth						x	R2
Air Temperature	x	x	x	x	x	x	W
Air Pressure	x	x	x	x	x	x	W
Water Depth	x	x	x	x	x	x	W
Wind Speed, Direction	x	x	x	x	x	x	W
Visibility	x	x	x	x	x	x	W

Runs 1-5 conducted in level ice

Run 6 organised ramming experiment on the Etagaulet Ridge

* Data Location:

R1: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.1, M.S.L. (1982)

R2: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.2, M.S.L. (1982)

R3: "M.V. ARCTIC Probe into Lake Melville, Labrador, Ice Property Measurements", Arctic Vessel and Marine Research Institute (1981)

T: Magnetic Tapes

W: Lake Melville Probe Work Sheets

DATA COLLECTION FOR THE DEDICATED RAMMING TESTS

Table 3

The turning circles were performed in several ship conditions:

a) With ship in full load, even keel condition with bubbler system operating and port rudder applied.
b) With ship in full load, even keel condition with bubbler system not operating and port rudder applied.
c) With ship in full load, even keel condition (longitudinal), heel to starboard, bubbler system operating and rudder amid-ships.
d) With ship in full load even keel condition (longitudinal), heel to starboard, bubbler system operating and starboard rudder applied. This test was repeated since the initial turn was only 20°.

It was not possible, due to lack of ice space, to complete the normal (open water) 540° manoeuvres or to complete the 270° manoeuvres recommended by NRC. In most cases only 90° turns could be effected with the one exception of a 180° turn.

2.3.2 Data

Table 4 displays the measurements performed in the nine dedicated manoeuvring tests in the Lake Melville probe. These tests consisted of three runs of rudder angle sensitivity, one channel break-out test and five turning circle tests.

2.4 Broken Channel Speed/Power Tests

2.4.1 Procedure

To determine the ship's speed/power relationship in a broken channel, several test runs were made. The ship was run at three different power settings. At each power, the ship's speed was allowed to stabilize before the recording run was started. Due to uncertainty about the Doppler Speed Log accuracy in this condition a check on ship speed was made using the "shoulder-mounted" television camera.

2.4.2 Data

The data collected in the broken channel speed/power tests at three different power settings is shown in Table 5. The tests were carried out while the vessel was departing the Lake, and the test location is depicted in Figure 2.

Run No.	1	2	3	4	5	6	7	8	9	Data Location*
Date (Month/Day)	3/1	3/1	3/1	3/3	3/1	3/1	3/3	3/3	3/3	
Start Time	13:40	14:15	14:40	08:19	14:47	17:04	08:58	10:16	12:46	
Stop Time	13:46	14:40	14:45	08:24	16:06	18:03	09:05	10:42	13:04	
Location = Lat. (N)	53° 43'	53° 42'	53° 42'	53° 51'	53° 40'	53° 40'	53° 52'	53° 52	53° 53'	
Long. (W)	59° 43'	59° 48'	59° 45'	59° 12'	59° 46'	59° 41'	59° 14'	59° 14'	59° 12'	
Permanent Data Tape No.	C12	C12	C12	C14	C12	C13	C4	C15	-	
Acquisition System: File No. (original tapes)	01	01	01	09	01	01	10	01	-	T
Vibration Measurement: Reel No.	4	4	4	-	4	4	-	-	-	T
Video Recording: Cassette No.	V3	V3	V3	V5	V3	V3	-	-	-	T
Ship Data										
Speed, Doppler	x	x	x	x	x	x	x	x	x	R1
Speed, Marker										
Speed, Video Monitor				x	x	x	x	x	x	R1
Heading	x	x	x	x	x	x	x	x	x	R1
Rudder	x	x	x		x	x	x	x	x	R1
Combinator	x	x	x	x	x	x	x	x	x	W
Stability Data	x	x	x	x	x	x	x	x	x	R1
R.P.M.					x	x	x	x	x	W
Engine Data					x	x	x	x	x	W
Electrical Load Data										
Propeller Shaft Thrust					x	x	x	x	x	W
Propeller Torque					x	x	x	x	x	W
Bubbler System	on	on	on	off	on	off	on	on	on	R1;W
Degrees of Turn	x	x	x	x	x	x	x	x	x	R1;W
Draught (F)	x	x	x	x	x	x	x	x	x	W
Draught (A)	x	x	x	x	x	x	x	x	x	W
Ice/Meteorological Data										
Ice Cover	x	x	x	x	x	x	x	x	x	R2
Ice Thickness	x	x	x	x	x	x	x	x	x	R2
Snow Cover										
Flexural Strength										
Confined Compressive Strength		x	x				x	x	x	R2
Unconfined Compressive Strength							x	x	x	R2
Ice Temperature Profile										
Ice Salinity Profile							x	x		R2
Crystallography							x	x	x	R3
Ridge Thickness Profile										
Ridge Consolidation Profile										
Air Temperature				x			x	x	x	W
Air Pressure	x	x	x	x			x	x	x	W
Water Depth	x	x	x						x	W
Wind Speed, Direction	x	x	x	x			x	x	x	W
Visibility				x			x		x	W

Runs 1-3 for rudder angle sensitivity test Run 4 channel breakout test
Runs 5-9 turning circle test

* Data Location:

R1: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.1, M.S.L. (1982)

R2: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.2, M.S.L. (1982)

R3: "M.V. ARCTIC Probe into Lake Melville, Labrador, Ice Property Measurements", Arctic Vessel and Marine Research Institute (1981)

T: Magnetic Tapes

W: Lake Melville Probe Work Sheets

DATA COLLECTION FOR THE DEDICATED MANOEUVRING TESTS

Table 4

Run No.	1	2	3	Data Location*
Date (Month/Day)	3/3	3/3	3/3	
Start Time	15:38	15:07	15:20	
Stop Time	15:41	15:11	15:25	
Location = Lat. (N)	54° 52'	54° 53'	54° 54'	
Long. (W)	59° 01'	59° 00'	58° 59'	
Permanent Data Tape No.	C16	C16	C16	
Acquisition System: File No. (original tapes)	01	01	01	T
Vibration Measurement: Reel No.	-	-	-	
Video Recording: Cassette No.	V7	V7	V7	T
Ship Data				
Speed, Doppler	x	x	x	R1
Speed, Marker				
Speed, Video Monitor	x	x	x	R1
Heading	x	x	x	W
Rudder	x	x	x	W
Combinator	x	x	x	W
Stability Data	x	x	x	W
R.P.M.	x	x	x	W
Engine Data	x	x	x	W
Propeller Shaft Thrust	x	x	x	W
Propeller Torque	x	x	x	W
Bubbler System	off	off	off	W
Draught (F)	x	x	x	W
Draught (A)	x	x	x	W
Ice/Meteorological Data				
Ice Cover, In Channel	x	x	x	R2
Ice Thickness	x	x	x	R2
Snow Cover				
Flexural Strength				
Confined Compressive Strength				
Unconfined Compressive Strength				
Ice Temperature Profile				
Ice Salinity Profile				
Crystallography				
Air Temperature	x	x	x	W
Air Pressure	x	x	x	W
Water Depth	x			W
Wind Speed, Direction			x	W
Visibility	x	x	x	W

* Data Location:

R1: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.1, M.S.L. (1982)

R2: "M.V. ARCTIC Experimental Voyage to Lake Melville, Labrador, in Feb/Mar 1981", Vol.2, M.S.L. (1982)

R3: "M.V. ARCTIC Probe into Lake Melville, Labrador, Ice Property Measurements", Arctic Vessel and Marine Research Institute (1981)

T: Magnetic Tapes

W: Lake Melville Probe Work Sheets

DATA COLLECTION FOR THE BROKEN CHANNEL SPEED/POWER TESTS

Table 5

2.5 Hull, Propeller Shafting and Rudder Stock Vibration Data & Analysis

2.5.1 Procedure

Measurements of hull vibration of M.V. ARCTIC while navigating in ice has been previously measured and reported by Lloyd's Register of Shipping (LRS), Hull Structures Department, London. The study was carried out during the Baffin Island trials held in October 1980 under the sponsorship of the Transportation Development Centre (TDC).

The LRS vibration trials report made several recommendations: that should further studies of hull vibration be carried out,

- additional accelerometers should be employed to more clearly define the higher modes of vibration and,
- accelerometer signal amplifiers should be used to enable the resonant frequencies excited to be more precisely defined.

It was decided to repeat the previous measurement exercise and to implement the LRS recommendations, and also to utilize additional instrumentation to investigate the vibratory behaviour of the propeller shaft and rudder stock.

The Technical Investigations Department of LRS were invited to carry out the necessary instrumentation work for this investigation and to record the signals of vibration and strain on magnetic tape during the trans-Atlantic crossing of the ship from the Elbe and while the ship was on trials in Lake Melville.

All signals from the instrumentation amplifiers were recorded as analogue signals on magnetic tape by a 14-channel Ampex FM tape recorder Type FR1300A. With one exception, all records were made at a tape speed of 3.75 inches per second providing a frequency response from Direct Current (D.C.) or frequency = 0 Hz to nominally 2 kHz. One block of recordings was made at a tape speed of 15 inches per second providing a larger frequency band width to define any high frequencies which may have been excited.

Signals of hull vibration were recorded from three types of accelerometers suitably connected to their respective power packs and to a Bell and Howell D.C. amplifier system. All accelerometers were fitted to magnetic bases to allow ease of positioning and change in orientation on the ship's steel work, as circumstances required. Nine accelerometers were of the seismic unbonded strain gauge type, which had a linear output over the frequency range - D.C. to 15 Hz, and were positioned on the main deck of the ship. Five accelerometers were of the pieso-electric type

and had a linear output over the frequency range - 1 Hz to 100 Hz; these accelerometers were fitted to the "poop deck" and in the "forecastle head" to detect any high frequency accelerations which might have been excited by large impact when the ship was in ice.

Shaft torque measurements were derived from the output of strain gauges arranged in a full "wheatstone bridge" configuration and bonded at 45° to the axis of the propeller shaft close to the forward stern bush. The signals of torsional strain from the strain gauges were transferred from the shaft to a demodulator by means of a Phillips telemetry system, and then amplified before being recorded by the tape recorder.

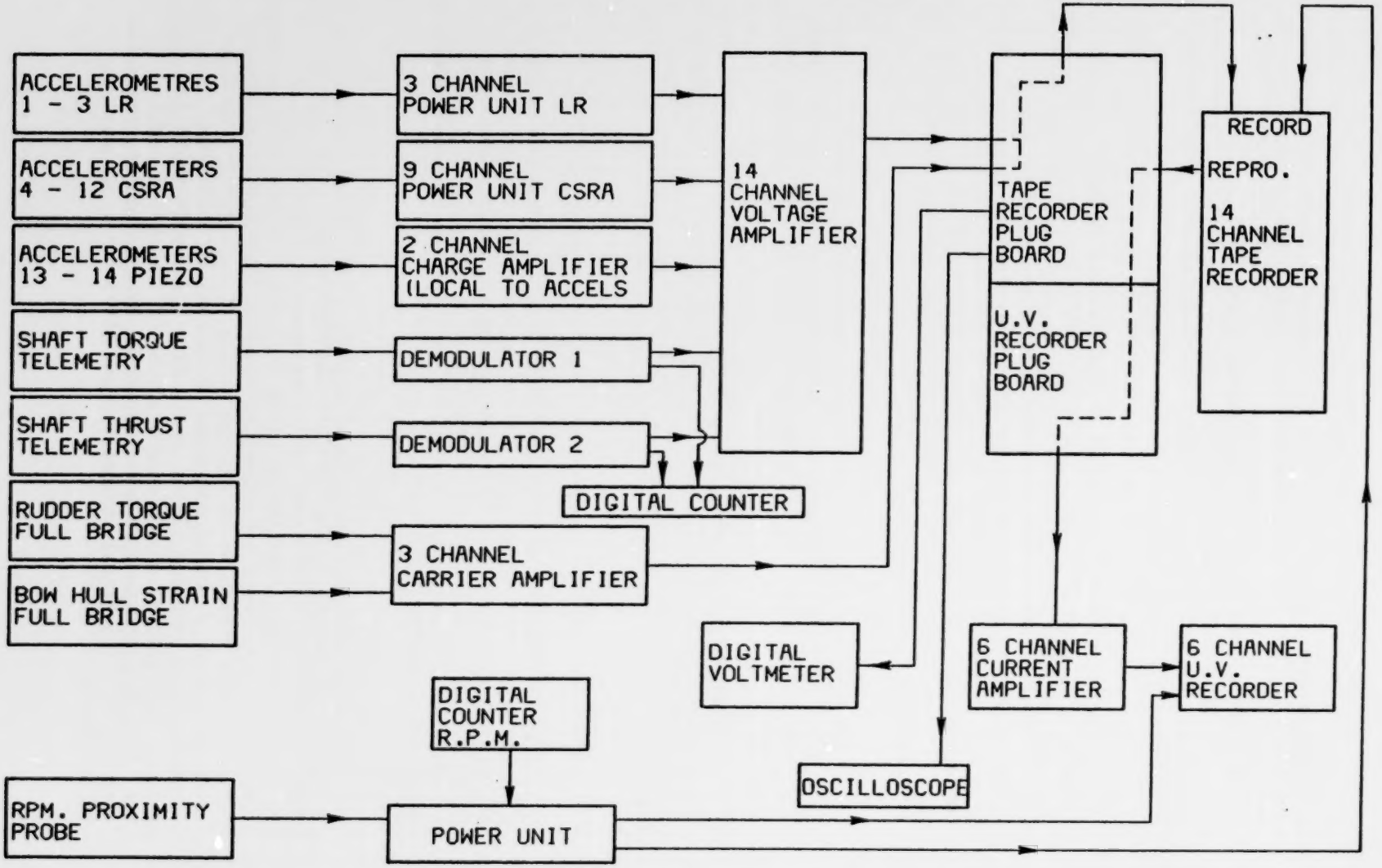
Shaft dynamic thrust measurements were derived from the signals of eight strain gauges bonded to the shaft in a full "wheatstone bridge" configuration. The signals of axial strain from the gauges were transferred from the shaft to the tape recorder by a similar telemetry system to that used for the torsional strain system. The shaft torsional and axial strain telemetry systems had a linear response over the frequency range - D.C. to 2 kHz.

Mean torque and mean thrust were calculated from the change in frequency noted from the display of a Racal VLF Counter connected to the telemetry demodulators. The frequency counts were also recorded on the voice channel of the tape recorder for future analysis purposes.

Signals of rudder stock torsional strain and stem bar bending strain were recorded from the output of two strain gauges bonded to the respective surfaces in a full "wheatstone bridge" configuration. One gauge was bonded to the surface of the rudder stock immediately beneath the tillerhead, and the other to the stem bar at approximately the waterline level. Both gauges were suitably connected to a Bell and Howell Miniature Carrier Amplifier System.

Signals, from which shaft speed could be derived, were recorded on the magnetic tape as a single pulse at once per shaft revolution from the output of a proximity probe which sensed a target mounted on the propeller shaft. Shaft speed was continuously monitored during all recordings from the display of a Racal VLF Counter which translated the pulses directly into an RPM reading. A block diagram of the recording system is shown as Figure 3.

A total of approximately five hours of vibration data were recorded during the trans-Atlantic crossing and during the test period in Lake Melville. Due to the impracticality of analysing all of the data in detail, only those blocks of data which showed peaks, or other events which could be interpreted as of particular interest, were selected for detailed analysis.



TEST EQUIPMENT DISPLAY

FIGURE 3

INDEX OF DATA COLLECTED

Six channels of recorded data were selected to be representative of the whole. These channels were replayed through a low-pass filter at high speed and re-recorded onto a six channel chart recorder. The data was therefore compressed into manageable proportions for selection of the most significant and representative parts of the records for harmonic analysis. The selection was made on the basis of peak events on any one channel.

Twelve samples of recordings of hull vibrations and nine samples of recordings of propeller shaft vibratory torque were selected for harmonic analysis. In the case of hull vibration data blocks, all channels in each block, in general totalling twelve data channels per block, were replayed through a low-pass filter to remove the high frequency 'noise' from the signals. The data was passed to an "Analogue to Digital Converter" and the digitised data stored on 'floppy disc'. In the case of vibratory torque records, some individually selected records of torque were exclusively digitised for analysis.

The digitised data was analysed for amplitude and harmonic content by a Hewlett Packard 9845 desk top computer using Fast Fourier Transform (FFT) methods. A permanent record of all data analysed was printed in the form of:

a) frequency/amplitude spectra and,
b) the reconstructed signal in real time from which the spectra was derived.

2.5.2 Data

Table 6 details the total recording data which has been generated with the Ampex FM tape recorder in the measurements of hull, propeller shafting and rudder stock vibrations. A total of approximately five hours of vibration data were recorded on five reels of FM tape during the trans-Atlantic crossing and during the test periods in Lake Melville as described in Sections 2.1 - 2.4.

The data collected consists of signals from accelerometers, rudder torque, shaft torque, thrust and RPM and the strain gauge response at stem bar near the water-line level. As shown in the table, the accelerometers were distributed along the length of the ship and placed over the ship's frames and other positions of substantial stiffness. The positions were chosen to be representative of hull girder vibration response and would not be subjected to excessive local vibrations. The accelerometers were positioned on the main deck, with their sensitive axis on the vertical or transverse planes of the ship's centre line or in the vertical plane to port and starboard. By this method, the hull response in the vertical, transverse and torsional modes was investigated.

Date Y/M/D	Reel Number	Record Number	Accelerometers*																		Shaft Torque	Shaft Thrust	Rudder Torque	Bow Strain Gauge	RPM
			-10		0		60		77			109			128		160			196		206					
			c t		p v	s v	c v	c t	p v	s v	c v	c t	p v	s v	c v	c t	s v	p v	c v	c t	s t	p v	p t	s v					
82-2-19	1	1																											
		2																											
		3																											
		4																											
81-2-23	1	5	x		x	x	x			x			x			x			x			x		x					
		6	x		x	x	x			x			x			x			x			x		x					
		7	x		x	x	x			x			x			x			x			x		x					
81-2-24	1	8	x		x	x	x			x			x			x			x			x		x					
		9	x					x			x			x			x			x			x		x		x			
81-2-25	1	10	x		x	x	x			x			x			x			x					x		x			
		11	x		x	x	x			x			x			x			x					x		x			
81-2-26	1	12	x		x	x	x			x			x			x			x	x									
81-2-27	1	13	x		x	x	x			x			x			x			x	x				x		x			
	1	14	x		x	x	x			x			x			x			x		x			x		x			
	2	15	x		x	x			x	x		x		x			x	x			x			x		x			
		16	x		x	x		x			x		x			x					x			x		x			
		17	x		x	x		x			x		x		x					x	x			x		x			
		18	x		x	x		x		x			x			x			x		x			x		x			
		19	x		x	x		x		x			x		x				x					x		x			
		20	x		x	x		x		x			x			x			x					x		x			
		21	← Voltage Calibration →																										
81-2-28	3	22	x		x	x			x	x		x		x			x	x			x			x		x			
		23	x		x	x			x	x		x		x			x	x											
		24	x		x	x			x	x		x		x			x	x					x			x			
		25	x		x	x			x	x		x		x			x	x			x	x							
		26	x		x	x			x	x		x		x			x	x			x	x							
		27	x		x	x	x				x		x				x				x					x			
		28	x		x	x		x				x			x				x		x								
	4	29	x		x	x		x				x			x				x		x								
		30	x		x	x		x				x			x				x		x								
		31	x		x	x		x				x			x				x		x	x							
81-3-1	4	32	←												→ Voltage Calibration														
		33	x		x	x		x			x			x			x	x											
		34	x		x	x		x			x			x			x	x											
		35	x		x	x		x			x			x			x	x											
		36	x		x	x		x			x			x			x	x											
81-3-2	5	37	x		x	x		x			x			x			x	x				x							
		38	x		x	x		x			x			x			x	x				x							
		39	←												→ Voltage Calibration														

* Accelerometer Orientation Nomenclature

sv Starboard Vertical cv Centre Vertical pv Port Vertical

st Starboard Transverse ct Centre Transverse pt Port Transverse

Positions of accelerometers defined by frame numbers are illustrated in Figure 4.

CATALOGUE OF DATA TAPES RECORDED WITH AMPEX FM TAPE RECORDER

IN HULL, PROPELLER SHAFTING AND RUDDER STOCK VIBRATION MEASUREMENTS

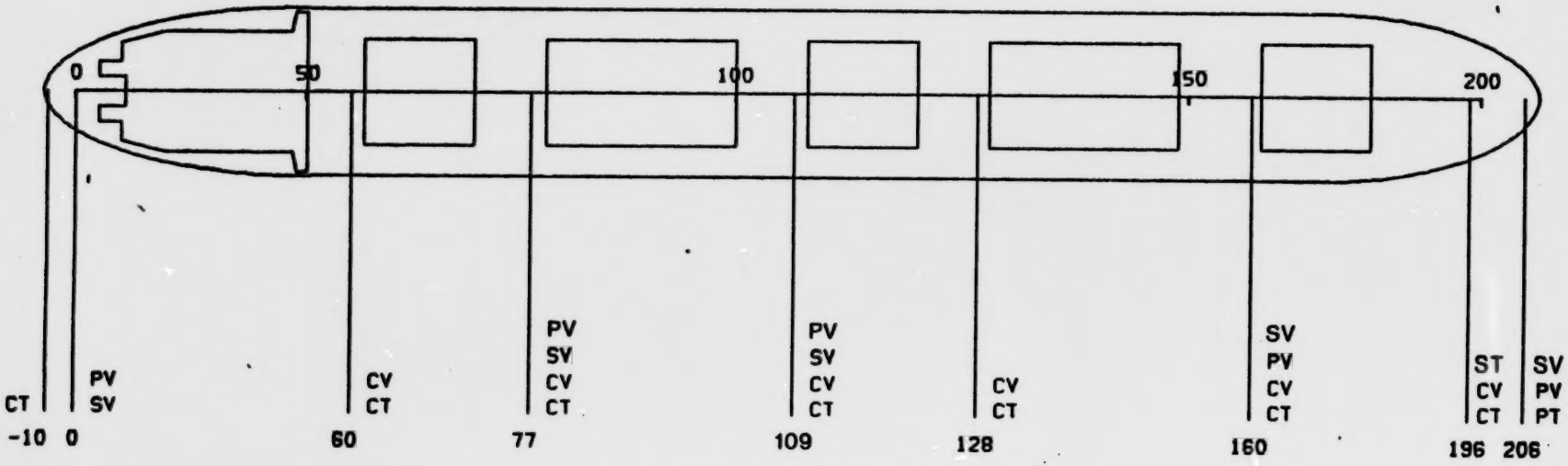
Table 6

INDEX OF DATA COLLECTED

ACCELEROMETER ORIENTATION NOMENCLATURE

SV STARBOARD VERTICAL
PV PORT VERTICAL
CV CENTRE VERTICAL

ST STARBOARD TRANSVERSE
PT PORT TRANSVERSE
CT CENTRE TRANSVERSE



FRAME NUMBERS

POSITIONS OF ACCELEROMETERS

FIGURE 4

In order that the analogue records of strain and vibration could be related in time with the digital recordings of hull strain and other data made by the "permanent data acquisition system" (Section 2.6), common times were used and recorded on the analogue tape recorder voice channel.

2.6 Hull Structure

2.6.1 Procedure

By the use of the ship's permanent instrumentation system eighty-six frame and plate strain gauges were recorded. Most of the gauges were installed between frame no. 179 and 200 on the starboard side of the bow. The sampling patterns of the strain gauges were selected to monitor the peak response of the hull structure at the ship's fore-end and the dynamic structural response of certain areas which were most susceptible to ice impacts. The sampling schemes for strain measurement were as follows:

1) In all data collection time, all strain gauges were sampled through the associated peak holding circuits at 1 sample/sec. The peak holding circuits enabled recording of the maximum strain values occurring in each 1-second interval between samples. This sampling pattern thus provided a distribution of maximum strain over all sensors in every second.

2) In addition, nine strain gauges located adjacent to the water-line level were sampled through the associated low pass filtering circuits at 100 samples/sec. This higher resolution data set allowed an illustration of the dynamic response of the hull structure to ice impacts. Recording of this additional data set was only activated when the ship was navigating through severe ice fields or performing ramming tests on level ice or pressure ridge.

After completion of data collection, the data tapes were reformatted using the University of British Columbia computer facility. All recorded data were rewritten onto 13 new magnetic tapes in higher tape density (1600 BPI). The reformatting process was to ensure that the end-of-file mark was properly installed for each data file which could not be achieved by the onboard data acquisition system.

The reformatted data tapes were then analysed with the Cybernet Computer System of Control Data Canada Ltd. (CDC). A tape analysis computer program originally obtained from Fenco Consultants Ltd. was used.

To establish a reliable measurement of ice-induced strains, all strain gauges used in data collection were individually zero-adjusted and calibrated before the test in Lake Melville and then recalibrated after the test. The calibrations were performed by shunting each gauge with a precision resistor of 28 k ohms to simulate an external load and the gauge response was measured and recorded on tape for subsequent analysis. Detailed analysis of the gauge calibration data and selected strain data recorded in different ice-breaking conditions was performed. The purpose of the analysis was to validate the strain data measured by the gauging system and to examine the structural response and its variation in the time and spatial domains during ice-breaking.

Figures 5 and 6 show respectively the location of strain gauges and their associated channel numbers on shell plating and supporting frame structure. The strain data of all these channels recorded during the ridge ramming test conducted on March 2, 1981 were examined.

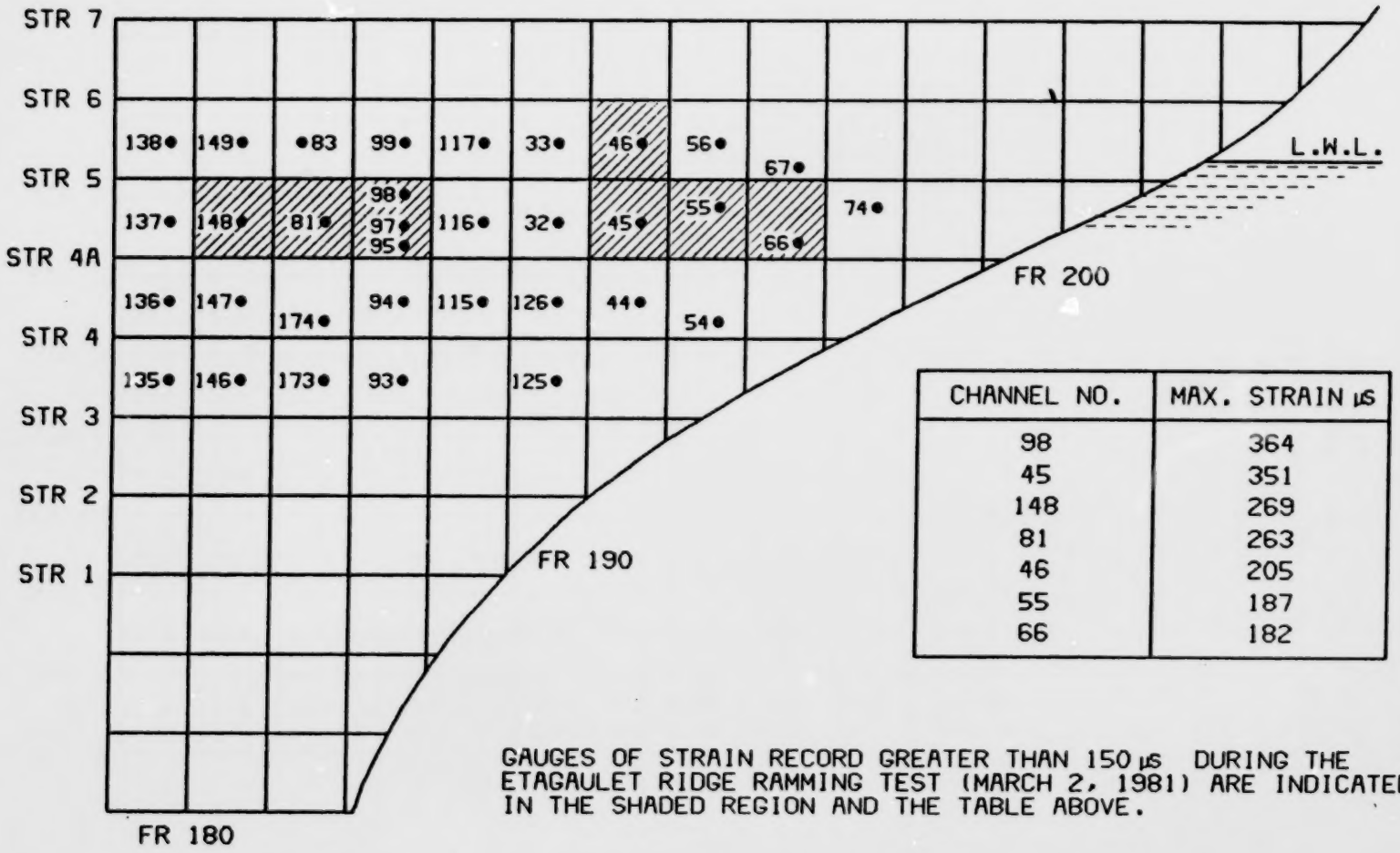
A number of level ice speed/power tests were conducted to determine the ship speed and power relationship as a function of various ice characteristics. The magnitude of ice-induced stress on hull structure and its variation in frequency at different ship speed was examined.

To assess the variation of strain gauge response, the "peak" strain data sampled at one per second of some ten selected gauges recorded during each speed/power test were investigated.

2.6.2 Data

Table 7 details all the recorded data produced with the permanent data acquisition system during the test periods of the Lake Melville probe. A total of 17 original magnetic tapes were recorded with the onboard Rolm model 1603A computer. For cross reference, both the original tapes and the reformatted tapes are listed in the table along with the recording times and sampling modes. The two different sampling patterns employed during the test periods are displayed in Table 8, in which the channel number, sensor, sampling rate and recording mode are tabulated.

In addition to strain gauge records relating to hull structure response monitoring, the data tapes recorded from the permanent instrumentation system also contain relevant information on propulsion, steering and ship performance parameters as detailed in Tables 3, 4 and 5.



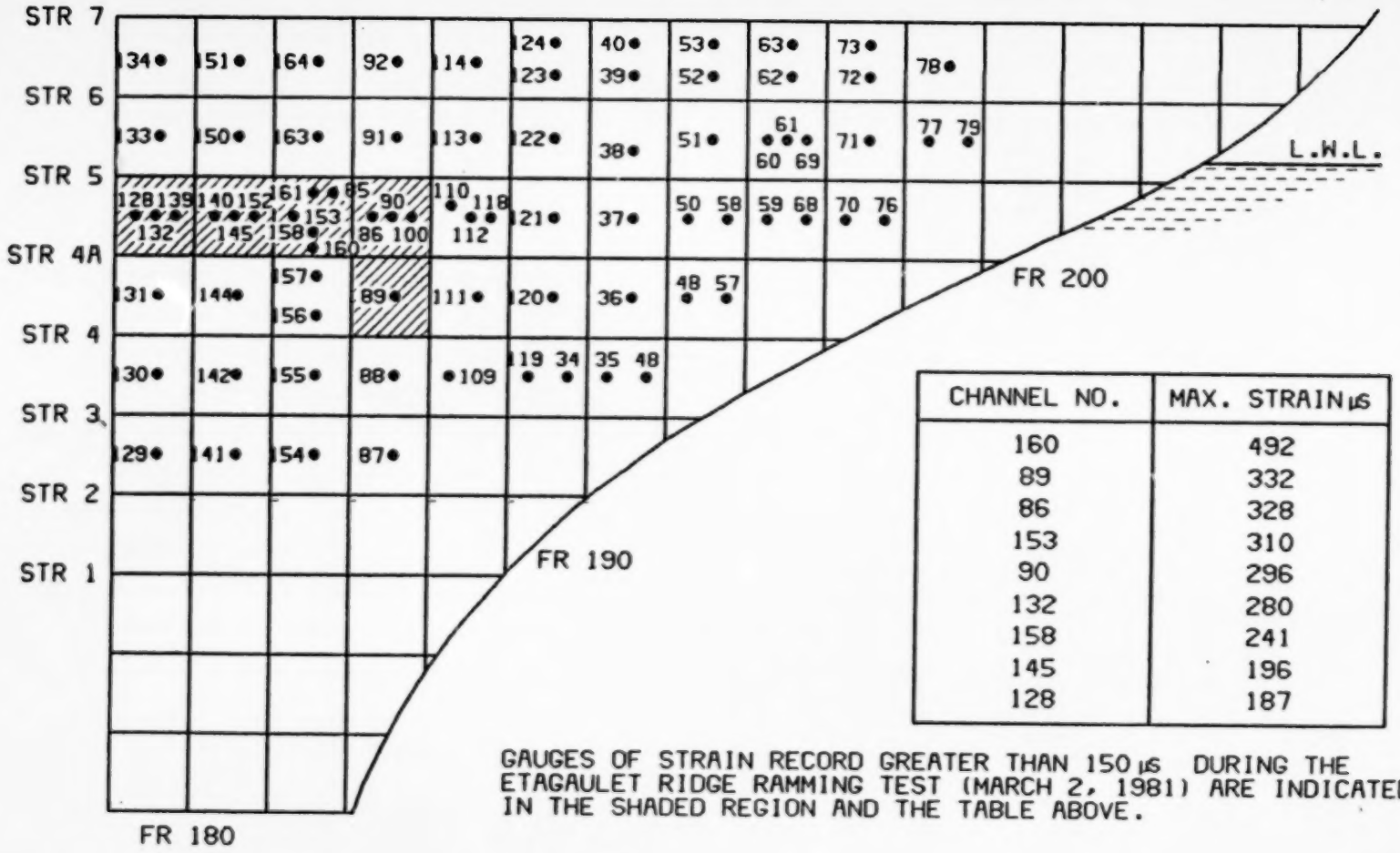
CHANNEL NO.	MAX. STRAIN μs
98	364
45	351
148	269
81	263
46	205
55	187
66	182

GAUGES OF STRAIN RECORD GREATER THAN 150 μs DURING THE ETAGAULET RIDGE RAMMING TEST (MARCH 2, 1981) ARE INDICATED IN THE SHADED REGION AND THE TABLE ABOVE.

LOCATION OF PLATE STRAIN GAUGES
AND THEIR ASSOCIATED CHANNEL NUMBERS

FIGURE 5

INDEX OF DATA COLLECTED



CHANNEL NO.	MAX. STRAIN με
160	492
89	332
86	328
153	310
90	296
132	280
158	241
145	196
128	187

GAUGES OF STRAIN RECORD GREATER THAN 150 με DURING THE ETAGAULET RIDGE RAMMING TEST (MARCH 2, 1981) ARE INDICATED IN THE SHADED REGION AND THE TABLE ABOVE.

LOCATION OF FRAME STRAIN GAUGES
AND THEIR ASSOCIATED CHANNEL NUMBERS

FIGURE 6

MIC-182-34 REV.A 81.08.20 MC0034 A1

Date	Time	Original Tapes		Reformatted Tapes		Sampling Mode
Y/M/D	Hr/Min/Sec	Tape ID	File No.	Tape ID	File No.	
81-2-23	13:14:00 - 13:17:02	C1	01	C1[1]	01	Calib.[2] CH.32-47
	13:18:10 - 13:20:07	C1	02	C1	02	Calib. CH.48-63
	13:21:55 - 13:25:06	C1	03	C1	03	Calib. CH.64-79
	13:26:23 - 13:28:34	C1	04	C1	04	Calib. CH.80-95
	13:30:10 - 13:32:25	C1	05	C1	05	Calib. CH.96-111
	13:33:30 - 13:35:31	C1	06	C1	06	Calib. CH.112-127
	13:37:38 - 13:40:09	C1	07	C1	07	Calib. CH.128-143
	13:40:52 - 13:42:17	C1	08	C1	08	Calib. CH.144-159
	13:44:18 - 13:46:45	C1	09	C1	09	Calib. CH.160-175
	13:48:48 - 13:50:33	C1	10	C1	10	Calib. CH.16-31
81-2-25	07:46:10 - 08:49:14	C3	00	C3	01	Pattern "A" 3)
	08:56:14 -	C2	01	C2	01	Pattern "A"
	10:05:53 - 11:13:24	C4	01	C4	01	Pattern "A"
	17:58:52 - 18:08:09	C5	00	C1	11	Pattern "A"
	18:49:50 - 18:51:53	C5	02	C1	12	Calib. CH.16-31
	18:52:50 - 18:55:01	C5	03	C1	13	Calib. CH.32-47
	18:55:30 - 18:57:56	C5	04	C1	14	Calib. CH.48-63
	18:58:30 - 19:00:53	C5	05	C1	15	Calib. CH.64-75
	19:10:30 - 19:12:51	C6	01	C1	16	Calib. CH.80-95
	19:13:30 - 19:16:16	C6	02	C1	17	Calib. CH.96-111
	19:16:41 - 19:16:51	C6	03	C1	18	Calib. CH.112-127
	19:26:50 - 19:28:46	C7	01	C1	19	Calib. CH.128-143
	19:28:55 - 19:30:56	C7	02	C1	20	Calib. CH.128-143
	19:31:38 - 19:33:48	C7	03	C1	21	Calib. CH.144-159
	19:34:30 - 19:37:08	C7	04	C1	22	Calib. CH.160-175
81-2-27	09:16:12 - 12:23:02	C8	01	C8	01	Pattern "B" 3)
	12:23:55 - 15:13:05	C9	01	C9	01	Pattern "B"
	15:44:30 - 17:06:15	C10	01	C10	01	Pattern "B"

CATALOGUE OF DATA TAPES RECORDED WITH THE PERMANENT DATA ACQUISITION SYSTEM

TABLE 7

Date	Time	Original Tapes		Reformatted Tapes		Sampling Mode
Y/M/D	Hr/Min/Sec	Tape ID	File No.	Tape ID	File No.	
81-2-28	13:42:59 - 14:05:02	C10	03	C10	03	Pattern "A"
81-3-01	08:50:30 - 11:58:24	C11	01	C11	01	Pattern "B"
	11:59:41 - 15:12:22	C12	01	C12	01	Pattern "B"
	15:14:53 - 18:19:59	C13	01	C13	01	Pattern "B"
81-3-02	14:15:50 - 14:19:27	C14	01	C14	01	Pattern "A"
	14:23:30 - 14:26:09	C14	02	C14	02	Pattern "A"
	14:31:50 - 14:37:36	C14	03	C14	03	Pattern "A"
	14:45:13 - 14:49:16	C14	04	C14	04	Pattern "A"
	14:51:10 - 14:55:11	C14	05	C14	05	Pattern "A"
	15:48:30 - 14:54:53	C14	06	C14	06	Pattern "A"
	20:49:30 - 20:56:32	C14	07	C14	07	Pattern "A"
81-3-03	08:11:35 - 08:35:00	C14	09	C14	09	Pattern "B"
	08:55:58 - 10:13:49	C14	10	C14	10	Pattern "B"
	10:34:10 - 11:09:17	C15	01	C15	01	Pattern "B"
	11:15:50 - 11:16:56	C15	03	C15	03	Pattern "A"
	11:19:37 - 11:28:42	C15	04	C15	04	Pattern "A"
	11:30:10 - 11:30:56	C15	05	C15	05	Pattern "A"
	11:45:10 - 11:49:06	C15	06	C15	06	Pattern "B"
	13:11:40 - 16:11:45	C16	01	C16	01	Pattern "B"
81-3-04	10:01:16 - 10:02:46	C17	01	C1	23	Calib. CH.16-31
	10:03:31 - 10:09:09	C17	02	C1	24	Calib. CH.32-79
	10:10:34 - 10:14:19	C17	03	C1	25	Calib. CH.80-127
	10:14:54 - 10:18:33	C17	04	C1	26	Calib. CH.128-175

TABLE 7 (continued)

CATALOGUE OF DATA TAPES RECORDED WITH THE PERMENENT DATA ACQUISITION SYSTEM

Note: (1) Reformatted Tape C1 contains data of original tapes C1, C5, C6, C7, and C17.
(2) Data recorded for Strain Gauge Calibration. Sampling rate 10 per second and real mode were selected for the strain gauge channels as shown in the Table.
(3) Details of Sampling Patterns "A" and "B" are given in Table 8.

Channel No	Sensor	Recording Pattern				Channel No	Sensor	Recording Pattern			
		"A"		"B"				"A"		"B"	
		Sampling Rate*	Recording Mode**	Sampling Rate*	Recording Mode**			Sampling Rate*	Recording Mode**	Sampling Rate*	Recording Mode**
1	Heave (Bow)	3	R	3	R	49	S/G 1925-64	2	P	2	P
2	Sway (Bow)	3	R	3	R	50	S/G 1925-65	2	P	2	P
11	Filter for Heave (Bow)	3	R	3	R	51	S/G 1930-66	2	P	2	P
12	Filter for Sway (Bow)	3	R	3	R	53	Filter for S/G 1910-61	5	R	-	-
13	Filter for Surge (Bow)	3	R	3	R	54	S/G 1930-154	2	P	2	P
19	S/G 1850-104	2	P	2	P	55	S/G 1930-155	2	P	2	P
20	S/G 1850-175	2	P	2	P	57	S/G 1935-69	2	P	2	P
21	S/G 1870-105	2	P	2	P	58	S/G 1935-70	2	P	2	P
26	S/G 1910-107	2	P	2	P	59	S/G 1945-71	2	P	2	P
29	S/G 1950-109	2	P	2	P	60	S/G 1945-72	2	P	2	P
31	Surge (Bow)	3	R	3	R	63	S/G 1950-75	2	P	2	P
33	S/G 1890-150	2	P	2	P	64	Filter for S/G 1930-155	5	R	-	-
34	S/G 1895-92	2	P	2	P	65	Filter for S/G 1935-70	5	R	-	-
35	S/G 1905-57	2	P	2	P	66	S/G 1950-157	2	P	2	P
36	S/G 1910-58	2	P	2	P	67	S/G 1950-158	2	P	2	P
37	S/G 1910-59	2	P	2	P	68	S/G 1955-78	2	P	2	P
38	S/G 1910-60	2	P	2	P	69	S/G 1955-79	2	P	2	P
39	S/G 1910-61	2	P	2	P	70	S/G 1965-80	2	P	2	P
40	S/G 1910-62	2	P	2	P	71	S/G 1970-81	2	P	2	P
42	S/G 1910-91	2	P	2	P	72	S/G 1970-82	2	P	2	P
43	S/G 1910-151	2	P	2	P	73	S/G 1970-83	2	P	2	P
45	S/G 1910-161	2	P	2	P	74	S/G 1970-159	2	P	2	P
46	S/G 1910-153	2	P	2	P	75	S/G 1970-160	2	P	2	P
48	S/G 1915-63	2	P	2	P	78	S/G 1990-86	2	P	2	P

M.V. ARCTIC PERMANENT DATA ACQUISITION SYSTEM.

(SAMPLING MODES USED DURING TEST PERIODS OF THE LAKE MELVILLE PROBE)

TABLE 8

INDEX OF DATA COLLECTED

Channel No	Sensor	Recording Pattern				Channel No	Sensor	Recording Pattern			
		"A"		"B"				"A"		"B"	
		Sampling Rate*	Recording Mode**	Sampling Rate*	Recording Mode**			Sampling Rate*	Recording Mode**	Sampling Rate*	Recording Mode**
80	S/G 1830-143	2	P	2	P	120	S/G 1890-52	2	P	2	P
81	S/G 1830-131	2	P	2	P	121	S/G 1890-53	2	P	2	P
82	S/G 1830-144	2	P	2	P	125	Filter for S/G 1890-53	5	R	-	-
83	S/G 1830-145	2	P	2	P	126	S/G 1890-148	2	P	2	P
85	S/G 1835-30	2	P	2	P	127	S/G 1840-50	2	P	2	P
86	S/G 1845-31	2	P	2	P	128	S/G 1785-1	2	P	2	P
89	S/G 1850-34	2	P	2	P	129	S/G 1790-2	2	P	2	P
90	S/G 1850-35	2	P	2	P	132	S/G 1790-5	2	P	2	P
91	S/G 1850-36	2	P	2	P	133	S/G 1790-6	2	P	2	P
95	S/G 1850-135	2	P	2	P	134	S/G 1790-7	2	P	2	P
97	S/G 1850-137	2	P	2	P	138	S/G 1790-124	2	P	2	P
98	S/G 1850-138	2	P	2	P	145	S/G 1810-13	2	P	2	P
101	S/G 1840-201	2	P	2	P	147	S/G 1810-126	2	P	2	P
104	S/G 1850-204	2	P	2	P	148	S/G 1810-127	2	P	2	P
105	S/G 1840-93	2	P	2	P	152	S/G 1810-16	2	P	2	P
106	S/G 1840-94	2	P	2	P	153	S/G 1825-17	2	P	2	P
107	Filter for S/G 1830-131	5	R	-	-	155	S/G 1830-19	2	P	2	P
108	S/G 1840-96	2	P	2	P	157	S/G 1830-21	2	P	2	P
109	Filter for S/G 1850-35	5	R	-	-	158	S/G 1830-22	2	P	2	P
110	S/G 1865-40	2	P	2	P	160	S/G 1830-23	2	P	2	P
111	S/G 1870-41	2	P	2	P	161	S/G 1830-24	2	P	2	P
113	S/G 1870-43	2	P	2	P	162	S/G 1830-25	2	P	2	P
117	S/G 1870-142	2	P	2	P	163	S/G 1830-26	2	P	2	P
118	S/G 1875-46	2	P	2	P	164	Filter for S/G 1830-23	5	R	-	-

M.V. ARCTIC PERMANENT DATA ACQUISITION SYSTEM

(SAMPLING MODES USED DURING TEST PERIODS OF THE LAKE MELVILLE PROBE)

(con[illegible])

Channel No	Sensor	Recording Pattern "A" Sampling Rate*	Recording Pattern "A" Recording Mode**	Recording Pattern "B" Sampling Rate*	Recording Pattern "B" Recording Mode**	Channel No	Sensor	Recording Pattern "A" Sampling Rate*	Recording Pattern "A" Recording Mode**	Recording Pattern "B" Sampling Rate*	Recording Pattern "B" Recording Mode**
165	Filter for S/G 1810-13	5	R	-	-	214	Heave (Stern)	3	R	3	R
166	S/G 1830-29	2	P	2	P	215	Filter for Surge (Stern)	3	R	3	R
169	S/G 1830-193	2	P	2	P	216	Filter for Sway (Stern)	3	R	3	R
173	Filter for S/G 1810-127	5	R	-	-	217	Filter for Heave (Stern)	3	R	3	R
174	S/G 1830-130	2	P	2	P	233	Wind Speed	2	R	2	R
198	Thrust	2	R	2	R	234	Wind Direction	2	R	2	R
199	Fuel Rack	2	R	2	R	236	Doppler	2	R	2	R
200	Rudder Response	2	R	2	R	237	Ship Heading - S	2	R	2	R
201	Propeller Response	2	R	2	R	238	Ship Heading - C	2	R	2	R
202	Rudder D.P.	2	R	2	R	239	Pitch	2	R	2	R
208	Torque	2	R	2	R	240	Roll	2	R	2	R
211	Shaft Speed Indicator	2	R	2	R	244	Propeller Command	2	R	2	R
212	Surge (Stern)	3	R	3	R	245	Rudder Command	2	R	2	R
213	Sway (Stern)	3	R	3	R						

* Sampling Rate Index = 2 (1/sec)
3 (10/sec)
5 (100/sec)

** Recording Mode = R (Real Mode)
P (Peak Mode)

(Use of CH.239 and CH.240 starting from 81-3-01, 08:50:30; Use of CH.125 terminated after 81-3-03, 11:15:50)

M.V. ARCTIC PERMANENT DATA ACQUISITION SYSTEM.

(SAMPLING MODES USED DURING TEST PERIODS OF THE LAKE MELVILLE PROBE)

TABLE 8 (continued)

3.0 INDEX OF DATA COLLECTED

The following table summarizes the information which was collected during the M.V. ARCTIC Lake Melville Probe in February and March, 1981

DATA MEASUREMENT	DATA MEASUREMENT	DATA MEASUREMENT
A. Ship Data		**D. Vibration Measurement Data**
Time	Ice Temperature Profile (Vertical)	Accelerometers
Ship Location	Ice Salinity Profile (Vertical)	Shaft Torque
Ship Speed, Doppler Log	Crystallography	Shaft Thrust
Ship Speed, Marker Measurement	Ridge Thickness Profile (Horizontal)	Rudder Torque
Ship Speed, Video Monitoring	Ridge Consolidation Profile (Vertical)	Bow Strain
Heading	Air Temperature	
Rudder	Air Pressure	
Combinator Position	Water Depth	**E. Video Monitoring and Photography**
Stability Data - Trim, Heel	Wind Direction and Speed	
Draft Displacement	Visibility	Video Recording
RPM		Photography
Engine Data - Turbo Charge RPM	**C. Permanent Instrumentation System Data**	
Fuel Rack Position, Exhaust		
Temperature Before T.C.	Hull Strain Gauges	
Electrical Loads	Shaft Torque	
Propeller Shaft Thrust	Shaft Thrust	
Propeller Torque	Shaft RPM	
Bubbler System	Fuel Rack Setting	
Radius of Turn	Propeller Command/Response	
	Rudder Command/Response	
B. Ice and Meteorological Data	Rudder Differential Pressure	
	Ship Speed	
Ice Cover/Type	Ship Heading	
Ice Thickness	Pitch and Roll	
Snow Cover	Accelerations, Fore and Aft	
Ice Flexural Strength Test		
Ice Confined Compressive Test		
Ice Unconfined Compressive Test